Name ____________________

Marks:

2 1. a) In the design of a GPS system, what was the major factor that contributed to error in the position measurement?

2 b) The design of the centrifugal evaporator required that the mass flow rate of steam be determined. What was the underlying principle that was used in making this determination?

2 c) In an analysis of the incremental economic benefit of adding thermal insulation to the walls of a house, at what point is the addition of another increment of insulation not economic if we assume a 20 year payback period on the capital cost of construction?

2 d) In the design of the open pit in the geological engineering laboratory, the ore, shale and till were to be removed using a basic cone shape; however, the volume of the pit did not increase linearly with an increase in depth. Explain why?

Marks:

2 2. a) Describe a physical process that could be considered a 'growth' or 'decay' process.

2 b) What is the fundamental reason (physical explanation) for why all 'growth' or 'decay' curves have the same basic shape and mathematical equation?.

4 c) What is the mathematical form for an unbounded growth process? How is this equation related to the physical processes described in part b)?

2 d) How does the mathematical form change if the growth process is 'bounded'?

3. An organism undergoes 'undbounded' growth. It has a population of only 100 cells at an elapsed time of 100 days and at 1100 days a population of 1×10^{12}.
[Note: $\ln(x) = 2.303 \log(x)$]

8 a) Calculate the initial population of this organism and the growth rate constant.

2 b) Calculate the rate of growth at 100 days.

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2 4. a) Why would engineers and scientists perform regression analyses?

2 b) In a regression analysis, the sum of the squares of the errors is used instead of the sum of the errors. Explain why?

2 c) What is the significance of the sample correlation coefficient with respect to a regression analysis?

8 d) If a straight line($Y=mX+b$) best describes the relationship between X and Y experimental $data_i$, show that the necessary expressions for m and b are equal to:

$$m = \frac{N\sum_{i=1}^{N} Y_i X_i - \sum_{i=1}^{N} Y_i \sum_{i=1}^{N} X_i}{N\sum_{i=1}^{N} X_i^2 - \left(\sum_{i=1}^{N} X_i\right)^2} \quad \text{and} \quad b = \frac{\sum_{i=1}^{N} Y_i - m\sum_{i=1}^{N} X_i}{N}$$

Start from an expression for the sum of the squares of the errors. Consider X_i is the ith input and Y as the corresponding output where i = 1, 2, 3, ….. , N.

Marks:

2 5. a) As engineers, we will use integration to evaluate a variety of physical responses. For example, integrating an acceleration history (acceleration vs. time) will result in an expression for the velocity as a function of time. A constant term is always added to the results of these types of indefinite integration. What is required to determine the correct value of a constant term, resulting from indefinite integration?

b) A car is stopped at a stop line (there are no vehicles in front of it), waiting for a traffic light to change from red to green. When the light turns green, the driver of the car releases the brake and depresses the accelerator pedal. The car has an initial acceleration of 10 m/s^2 followed by a linearly decreasing acceleration with respect to time. The car is travelling with a constant velocity after 10 seconds of travel. After 15 seconds of travel from the traffic light, the car hits a brick wall that does not move under the impact.

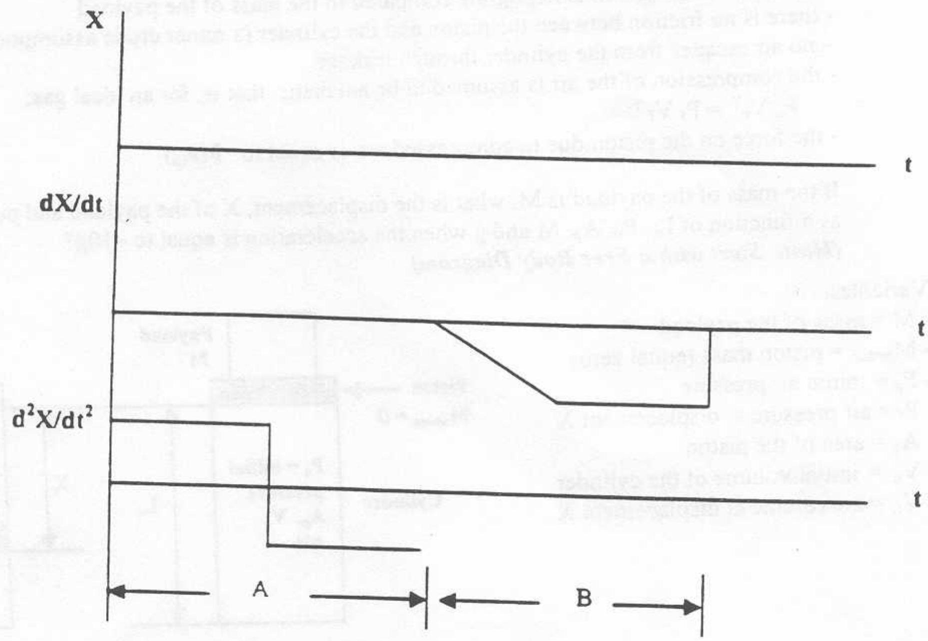
4 i) Sketch the acceleration history of the vehicle <u>between</u> the time that the car starts to move and the time that the car hits the wall. Choose appropriate labels and limits for the axes of the curve.

4 ii) Develop a mathematical description of the acceleration of the vehicle as a function of time, from the time the car starts until the car hits the wall.

2 iii) Develop a mathematical description for the velocity of the vehicle as a function of time, from the time the car starts until the car hits the wall.

Marks:

10 6. The figure shown below represents incomplete time histories of a parameter, X, and its first and second derivatives. During the "A" time period, complete the curves for X and dX/dt. Similarly, complete the curves for X and d^2X/dt^2 during the "B" time period. Assume that at time equal zero, X = 0 and dX/dt = 0.



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Marks:

10 7. A mechanical spring was used in the drop tower problem to stop the payload at the bottom. A decision has been made to replace the mechanical spring by an "air spring" as illustrated in Figure 1. The air spring consists of a cylinder and a moving piston. Air is sealed in the chamber and as the piston is forced down, the air is compressed, increasing the pressure in the cylinder. The following assumptions are made:

- the mass of the piston is negligible compared to the mass of the payload
- there is no friction between the piston and the cylinder (a rather crude assumption)
- no air escapes from the cylinder through leakage
- the compression of the air is assumed to be adiabatic, that is, for an ideal gas;
  $P_o V_o^{\gamma} = P_f V_f^{\gamma}$
- the force on the piston due to compressed air is equal to $P(A_p)$

If the mass of the payload is M, what is the displacement, X of the payload and piston as a function of L_o, P_o, A_p, M and g when the acceleration is equal to $-10g$?
(Hint: Start with a Free Body Diagram)

Variables:
- M = mass of the payload
- M_{piston} = piston mass (equal zero)
- P_o = initial air pressure
- P_f = air pressure at displacement X
- A_p = area of the piston
- V_o = initial volume of the cylinder
- V_f = air volume at displacement X